Induced Ferromagnetism at the Interface of Paramagnetic $CoCr_2O_4$ Epitaxial Thin Films

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Previous work on epitaxial manganite ($La_{0.7}Sr_{0.3}MnO_3$)-magnetite (Fe_3O_4) magnetic tunnel junctions (MTJs) have shown large junction magnetoresistance (JMR) from the use of a spinel-structure paramagnetic insulator(1) as the tunnel barrier. However, the use of $CoCr_2O_4$ (CCO) as the barrier in an isostructural magnetite-CCO-magnetite trilayer(2) yields small JMR. In addition, the trilayer exhibits room-temperature exchange coupling between the ferromagnetic electrodes across the 6nm thickness of the barrier. Such behavior is puzzling in light of the CCO bulk Curie temperature (95K), and single layer CCO thin films that show largely suppressed magnetization as measured by a SQUID magnetometer. We have grown 40nm layers of the ferromagnetic electrode materials $La_{0.7}Sr_{0.3}MnO_3$ and Fe_3O_4 as well as CCO via pulsed laser deposition on (110) SrTiO3 single crystalline substrates. Furthermore, 3nm CCO capping layers were grown on 40nm thick electrode films to study the magnetism and coupling at the paramagnet-ferromagnet interface. Soft x-ray magnetic circular dichroism (XMCD) spectroscopy on ALS beamline 4.0.2 indicates that octahedrally coordinated Cr atoms are strongly polarized by the underlying ferromagnetic oxide layers, but the tetrahedrally coordinated Co atoms are less strongly polarized. While the perovskite-structure manganite film weakly enhance the ferromagnetism of the CCO capping layer, the commensurate spinel Fe_3O_4–CCO interface provides unexpectedly strong coupling to above room temperature. Domain images taken in the PEEM2 photoemission electron microscope confirm that domains of magnetite ferromagnetically couple to CCO capping layers with thicknesses of 3nm and 6nm. The domain structure in CCO persists up to 500K on the Cr L3 edge, well above the T_c of CCO, but cannot be seen on the Co L3 edge even at room temperature. We attribute this strong inducement of ferromagnetic order in CCO to interface coupling to octahedrally coordinated Mn or Fe at electrode-barrier interfaces. Defects such as anti-phase boundaries at a perovskite-spinel interface suppress the exchange coupling of the paramagnetic capping layer, but the high quality interface between spinel-structure oxides allows for the persistence of the ferromagnetic state up to 6nm away from the ferromagnet-paramagnet interface.

(1) G. Hu and Y. Suzuki, Phys. Rev. Lett. 89, 276601 (2002).
(2) Chopdekar et al, J. Elec. Mat, Vol. 33, No 11, 1254-1258 (2004).